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Analyses of UHF TV Receiver Interference Immunities Considering Advanced Television

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Analyses of UHF TV Receiver Interference
Immunities Considering Advanced Television

EXECUTIVE SUMMARY

Implementation of advanced television (ATV) in the existing broadcast television bands will require some consideration of possible interference to conventional television receivers. The FCC Laboratory staff has prepared statistical analyses of a sample of television receivers to examine the impact ATV might have on the existing television receiver population. The results of the analyses are intended to provide guidance to the Commission and industry when considering the implementation of the ATV service.

UHF tuners of television receivers have limitations in their ability to reject interference from signals in the UHF television band. Because of these limitations, the FCC restricts the use of specific UHF channels above and below an assigned UHF channel. These restrictions, generally known as "UHF taboos", substantially reduce the number of UHF channels that are assignable to full power UHF television stations in a given geographic area.

This study analyzes taboo-related receiver performance from the standpoint of possible use of taboo channels to supplement existing spectrum for ATV implementation. We assume that an ATV augmentation transmitter will be collocated with a station's main television transmitter. The desired and undesired signals used in the study were conventional television signals, since the tests were originally intended to study interference between conventional television signals. However, the data are useful as a first step in studying ATV interference, since the characteristics of ATV augmentation signals have not been established. Note that the study results probably indicate more protection than will actually be needed. Although there is only speculation about the salient technical characteristics of ATV augmentation signals, they will surely be modified from the characteristics of conventional television signals and be specified to reduce interference to main transmitter signals.

The results of the study lead to the following conclusions:

1. Most of the taboo channels look favorable for potential use as ATV augmentation channels.

2. Taboo channels n+7, -7, +8, -8, and +15 may be described as providing less opportunity for exploitation as augmentation channels. (See note attached to Appendix C.)

Finally, the level of performance of the receivers analyzed in our study is much poorer than would be expected of future receivers designed to avoid taboo-related interference. The RF Monolithics receiver, built for the FCC, shows that general use of such receivers might enable the use of all the taboo channels for ATV.

I. INTRODUCTION

The FCC Laboratory staff has performed a study of the UHF interference immunity characteristics of contemporary television receivers. Television receivers have limitations in their ability to reject interference from undesired signals. Because of this lack of interference immunity, the Commission restricts the use of specific channels above and below an allocated UHF channel. These restrictions, generally known as "UHF taboos," substantially limit the use of the UHF television band in a given geographic area. 1

The Commission is currently examining alternative approaches for authorizing advanced television (ATV) systems that would provide for improved picture quality. Many of the technical designs for transmitting ATV signals require more spectrum than the 6 MHz currently used by broadcast television stations under the NTSC transmission system. One option the Commission is investigating is the possibility of authorizing "augmentation" channels that would provide stations with additional spectrum for ATV.

The primary purpose of this study is to develop information about taboo-related interference to support consideration of the possibility of using UHF taboo channels to provide spectrum for ATV augmentation channels. In particular, the study examines the performance characteristics of contemporary receivers, i.e. receivers that use electronic tuners. We believe such receivers are now used as the primary receiver in many, if not most, television households. Using the research findings, the study addresses the possibilities for using taboo-related channels for augmentation signal transmitters that would be collocated with existing NTSC television transmitters. 2

The study also mentions implications of a general introduction of television receivers with taboo-related performance corresponding to that of an advanced technology receiver developed for the Commission. (1,2,3)

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1 Brief descriptions of the UHF taboos are provided in Appendix A.

2 Collocation is important to consider because a transmitter's primary service area could experience interference from its own collocated taboo-related ATV signal.

II. STUDY DESIGN AND METHODOLOGY

This study analyzes previously reported data for UHF TV receiver immunities to interference from signals on taboo channels. The basic approach of the study is to identify the relative levels at which signals on each of the taboo channels, as compared to the channel to which the receiver is tuned, cause "just perceptible" interference to occur to reception. 3 The relative signal strengths are expressed in terms of undesired (taboo channel) to desired (tuned channel) signals. By this measure, receiver immunity to interference from signals on a given taboo channel increases with the ability to tolerate higher levels of the undesired signal level at any given level of the desired signal. Thus, the larger the U/D ratios, the better the receiver performance.

The study used a sample of television receivers representing receivers marketed in 1983. 4 However, the present receiver population may be assumed to contain a significant number of such receivers. To the present time there appear to have been no changes in electronically tuned receivers that would significantly affect the data base. The study provides estimates of interference to receivers intended for conventional television, not ATV. At the present time, there are no ATV receivers. The interference immunities of such receivers are unknown.

The actual desired and undesired signals were conventional television signals, since the tests were originally intended to study interference between such signals. (4) ATV augmentation signals are inadequately specified at present for interference test purposes. Application of the data to ATV results in simulating ATV augmentation with signals that have the same characteristics as conventional color television signals, e.g., the undesired signal level is specified as the level of the visual carrier. Both visual and aural carriers were present in the test signals. ATV systems are likely to operate with different characteristics than conventional stations and therefore will have interference characteristics that differ from the results estimated here. ATV approaches that use reduced signal levels and/or modified transmission methods for their augmentation channels generally can be expected to pose less interference to main transmitter signals. Therefore, the results of this study are likely to overestimate the interference potential of augmentation signals on taboo channels compared to conventional television signals on taboo channels. This study is a preliminary effort to estimate interference to

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3 Determinations of "just perceptible" interference as used herein were based on the observations of expert viewers. This interference criterion enhances the reproducibility of the viewers' observations. Under actual viewing conditions, this level of interference would probably not be noticed. It represents much less picture degradation than that on which transmitter service contours and the UHF taboo channel restrictions are now based. However, the criterion may be appropriate for interference to a primary NTSC service area from a collocated ATV augmentation transmitter.

4 The data analyzed in this study were originally tabulated and reported in reference 4.

conventional television receivers tuned to a conventional main channel operating with a collocated ATV augmentation channel.

Desired and undesired signals were introduced at the antenna terminals of a receiver under test. For a given desired signal level, the level of the undesired signal was varied to determine the level at which just perceptible interference occurred. Receiver interference immunity, the threshold U/D ratio, will differ for relatively strong desired signals compared to relatively weak desired signals.

The study, therefore, examined receiver interference thresholds at strong, moderate, and weak desired signal levels. The strong signal level used was -15 dBm. This represents a UHF broadcast station field strength of several hundred millivolts per meter and is approximately the level at which a receiver's tuner might exhibit overload. The weak signal level used was -55 dBm. This is intended to represent reception at a television station's Grade B contour, a boundary used to estimate a station's service area. The moderate signal level used was chosen as -35 dBm. This generally represents urban coverage. The study used previously reported data (4). Statistical analyses were performed to project the data to various percentages of the population represented by the sample receiver data base. In particular, analyses were made for 50, 80, 90, and 99 percent of this population.

The Receiver Sample

The sample of receivers used for this study consisted of 15 electronically tuned receivers, circa 1983. 5 We did not use random sampling but "cluster sampling." The sample does not represent the population in every aspect, but only in characteristics of interest. For example, electronically tuned color receivers were chosen because they appear to be the dominant choice as the primary receiver in television households. Mechanically tuned receivers were excluded because they tend to be less susceptible to UHF taboo interference than electronically tuned receivers and are becoming less important statistically. Some characteristics of the population, such as the picture tube sizes of table model and floor model receivers do not affect interference immunity. The sample was not chosen to represent the proportions of the various picture sizes in the population. In other characteristics the sample was deliberately structured to mirror the population. For example, fewer expensive receivers were included than "loss leaders" and more receivers were included from major brands than minor brands. Care was taken in the selection of the sample so that statistically valid inferences could be made for the population of receivers with regard to the characteristics of interest. Table 1 briefly describes each of the sample units.

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5 The procedures used to obtain the data are described in Appendix B.

Table 1

Brief Descriptions of Television Receivers
(Receivers numbered as in reference 4)

No. 1:	25" console, one knob tuner, Brand A
No. 2:	19" table model, frequency synthesized tuner, remote control, Brand A
No. 3:	19" table model, frequency synthesized tuner with remote, Brand B
No. 4:	19" table model, 12 channel tuner with remote, Brand C
No. 5:	25" console, frequency synthesized tuner with remote, Brand D
No. 6:	14" table model, 12 channel tuner with remote, Brand B
No. 7:	19" table model, frequency synthesized tuner with remote, Brand E
No. 8:	19" table model, frequency synthesized tuner with remote, Brand F
No. 9:	19" table model, frequency synthesized tuner, Brand G
No. 10:	19" table model, frequency synthesized tuner with remote, Brand G
No. 11:	19" table model, frequency synthesized tuner with remote, Brand H
No. 12:	20" table model, frequency synthesized tuner with remote, Brand I
No. 13:	14" portable, one knob tuner, Brand J
No. 14:	(not included in sample, mechanically tuned)
No. 15:	19" table model, frequency synthesized tuner with remote, Brand J
No. 16:	19" table model, one knob tuner, Brand A

Procedures for Statistical Analyses

The data analyzed for this study consist of U/D ratios found for various "test situations" applied to the same group of fifteen television receivers. In statistics these test situations are frequently called "treatments." In this study a test situation or treatment is characterized by:

1) The taboo phenomenon

2) The channel spacing of the interference (undesired) channel relative to the tuned (desired) channel; and,

3) The level of the desired channel signal.

Fourteen taboo channel spacings were analyzed with three desired signal levels, -15 dBm ("strong"), -35 dBm ("moderate"), and -55 dBm ("weak"). 6 This resulted in 42 treatments of the fifteen television receivers.

The analysis applied to each treatment examined the U/D ratios obtained for each receiver under the specific conditions of the treatment. In general, a treatment yielded fifteen data points, one for each receiver. 7 The data points are the undesired to desired signal ratios for each receiver, calculated from the desired signal level for the treatment and the undesired signal level reported for the mean observation of "just perceptible" interference as found by two observers. Additional information is given in Appendix B about the procedures used for obtaining individual data points.

Some elementary statistics were calculated previously for the data for the various treatments. (4) These were the mean, median, and range. These statistics were recomputed for the present study to exclude data from a mechanically tuned receiver. As discussed below, more sophisticated statistical procedures were used in the present study to extend statistics from the sample to the designated receiver population.

The data for each treatment were first examined for normality, i.e., whether the sample data were drawn from a population with a normal (i.e. gaussian)

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6 The FCC's taboo tables for allocations that are 2, 3, 4, and 5 channels removed from the tuned channel all concern intermodulation products. The study did not separately examine intermodulation combinations that are 3 and 5 channels removed from the tuned channel because the U/D ratios are evidently better (larger) than those for intermodulation combinations that were studied. Also, these intermodulation taboos would apparently be of little consequence in restricting ATV augmentation. See Appendix A for additional description of the UHF taboos.

7 In some treatments, the level of taboo channel signal necessary to cause just perceptible interference was higher for one or more of the observations than could be obtained from the generating equipment. Such observations were conservatively treated as missing data points.

probability distribution. The normality tests were performed through a computer program that uses a method similar to plotting the treatment data on normal probability paper. 8 On the basis of the guidance given in the documentation supplied with the program, normality was assumed if there were no systematic departures of the rankit plot from a linear trend and if the Wilk-Shapiro statistic were 0.94 or larger.

If a treatment exhibited normality, the cumulative normal distribution of the population was constructed using the standard deviation of the U/D ratios for the treatment and an adjusted, conservative estimate of the population mean U/D ratio. The value used as the adjusted population mean U/D ratio was the lower limit of the 90% confidence interval of the estimated population mean U/D ratio. This statistic was calculated for the treatment by the usual method using the t distribution. This biased estimate of the population mean had the effect of shifting the cumulative distribution of the population toward smaller U/D ratios. The effect is to render more pessimistic results in the sense that weaker undesired signal levels are estimated to cause interference. This is consistent with a posture of attempting to avoid television interference.

Some of the treatment data were skewed and therefore did not pass the test for normality. Interestingly, the means and medians of the U/D ratios for such treatments tended to coincide within a few decibels. Since there has been little interest in U/D ratios associated with protecting only the better receivers, the poorer (smaller) eight U/D ratios of a treatment exhibiting skew were examined for normality. This was done by using the values below the median with calculated values point for point as much above the median. If the fifteen data points constructed for such treatments from the smaller eight U/D data points demonstrated normality, the treatment was considered to be "conditionally normal." The original treatment data were used in calculating the estimate of the mean, because these data are more representative of the population. 9

Some treatments had as many as three missing U/D ratios. The adjusted estimate of the population mean for such a treatment was calculated as if the number of receivers was reduced by the number of missing values. This tended to make the adjusted estimate of the mean population U/D ratio smaller (poorer) than would have been calculated from a complete data set. Treatments with missing values were either not normalizable or conditionally normal. Obviously, such missing values would not affect the development of conditionally normal U/D ratios for a treatment.

The cumulative distribution for a treatment was plotted in terms of U/D ratios for "just perceptible" interference versus percentages of the population. Table 2 is a tabular summary of the results for the 42 treatments representing

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8 Wilk-Shapiro/Rankit Plots, "STATISTIX", NH Analytical Software, Roseville, MN 55113.

9 Conditionally normal treatments are indicated on Table 2.

the various desired signal levels. The table shows estimated "just perceptible" U/D ratio thresholds to protect 90% and 50% of the population. There was good agreement with values found using tolerance limit tables. Appendix C presents more complete results of the study than Table 2. This appendix includes U/D ratios for population percentages not given in Table 2 and has more detailed notes about the statistical analyses for the various treatments.

III. STUDY RESULTS

Table 2 summarizes the results of the study analyses. A more complete presentation of these results is presented in Appendix C.

Table 2

Summary of Results

Estimated Thresholds of Undesired to Desired
UHF TV Signal Ratios Needed to Protect 90 and 50
Percent of the Electronically Tuned Color TV Receiver Population

Undesired Signal(s) (Treatment)	Weak (-55 dBm) 90%/50% (a) U/D's in dB	Weak (-55 dBm) Std.Dev. in dB	Moderate (-35 dBm) 90%/50% (a) U/D's in dB	Moderate (-35 dBm) Std.Dev. in dB	Strong (-15 dBm) 90%/50% (a) U/D's in dB	Strong (-15 dBm) Std.Dev. in dB
	Desired Signal Strength					
Upper Adj. Channel (n+1)	(b)		0 (c)/ 9	7 (c), 5	-6 (c)/-1	4 (c), 4
Lower Adj. Channel (n-1)	-6 (c)/ 8	11 (c), 8	-6 (c)/ 5	9 (c), 6	-6 (d)/-1	4 (d), 4
Intermod. Chs.(n-2, n-4)	16 (c)/21	4 (c), 3	10/14	3	-4/ 1	4
Intermod. Chs.(n+2, n+4)	2 (c)/12	6 (c), 8	-2/ 6	6	-6/ 0	5
Cross Modulation Ch.(n+2)	17/25	6	8/17	7	-4 (d)/ 3	5 (d), 5
Cross Modulation Ch.(n-2)	21/27	4	13/20	5	(b)	
Cross Modulation Ch.(n-4)	30/36	5	(b)		(b)	
Half-IF (n+4)	(b)		-1/ 7	6	-5 (d)/ 1	5 (d), 5
IF Beat Ch.(n+7)	10/23	10	-8 (d)/10	14 (d),12	-14 (d)/ 0	11 (d), 7
IF Beat Ch.(n-7)	6/22	12	-2 (d)/13	12 (d),11	-12 (d)/ 2	11 (d), 7
IF Beat Ch.(n+8)	-5 (c)/21	21 (c),15	-17 (c)/ 9	20 (c),15	-17 (d)/-2	12 (d), 9
IF Beat Ch.(n-8)	10/26	13	-5 (d)/13	14 (d),12	-10 (d)/ 2	9 (d), 7
Sound Image Ch.(n+14)	-1/13	11	-2/ 8	8	-6/ 2	6
Picture Image Ch.(n+15)	-20/-7	10	-17/-10	5	-26/-19	5

Notes:

a: The U/D ratio for 50% of the population is the lower limit of the 90% confidence interval of the estimated mean population U/D ratio. The U/D ratio for 90% of the population was obtained from the normal cumulative distribution with the U/D ratio for 50% of the population and the standard deviation of the treatment data or conditionally normal data.

b: The treatment data were not normalizable. See Appendix C.

c: This value was obtained using conditionally normal data. The other value shown was obtained with the treatment data.

d: This value was obtained using conditionally normal data. The other value shown was obtained with the treatment data. The treatment data had one, two, or three missing U/D ratios. See Appendix C.

IV. DISCUSSION AND OBSERVATIONS

We observe that a station offering ATV service through a technical system that requires an augmentation channel most likely will transmit both its primary and augmentation signals from the same location (i.e., it will operate collocated primary and augmentation channel transmitters). Under the current allocations scheme, UHF channel assignments that are governed by the taboo restrictions serve different areas so that their potential for interference is limited to relatively small areas and correspondingly small populations. If two taboo channels are collocated, the areas served by the signals would, in general, be coincident and the area of potential interference would, therefore, cover the primary audience served by the signals. Thus, the population of TV viewers at risk would be much larger if taboo channels were collocated.

On this basis, it appears that if taboo channels are used to provide augmentation channels for ATV service, a significant increase in interference to stations' primary service areas may be possible. For discussion purposes in this study, we believe it is desirable to use conservative measures of impact. Therefore, we believe it is reasonable to consider using receiver interference immunity U/D ratios protecting 90% of the receiver population in situations where a station's primary audience may be affected by taboo channel interference. We also believe that it is reasonable to use the "just perceptible" interference criterion.

In interpreting the study results, we observe that the power level of ATV augmentation signals generally is expected to be 4 to 6 dB less than that of primary transmitter signals. ATV systems also are expected to use sophisticated techniques of modulation and signal power density management to achieve reductions in interference from augmentation signals.

The results in Table 2 show that for all of the taboo channels, receiver performance is poorest for the condition where a strong desired signal (-15 dBm) is present. This condition thus represents the "worst case" situation for receiver performance. As indicated in Table 2, protection from a collocated transmitter that is sufficient for strong desired signals plainly also will be sufficient for moderate and weak signals. The strong signal results are shown graphically in Figure 1. The upward arrows on this figure indicate cases where receiver performance is known to be better than the level shown and the data points indicated by "RF" are for the improved technology receiver developed for the Commission by RF Monolithics, Inc.

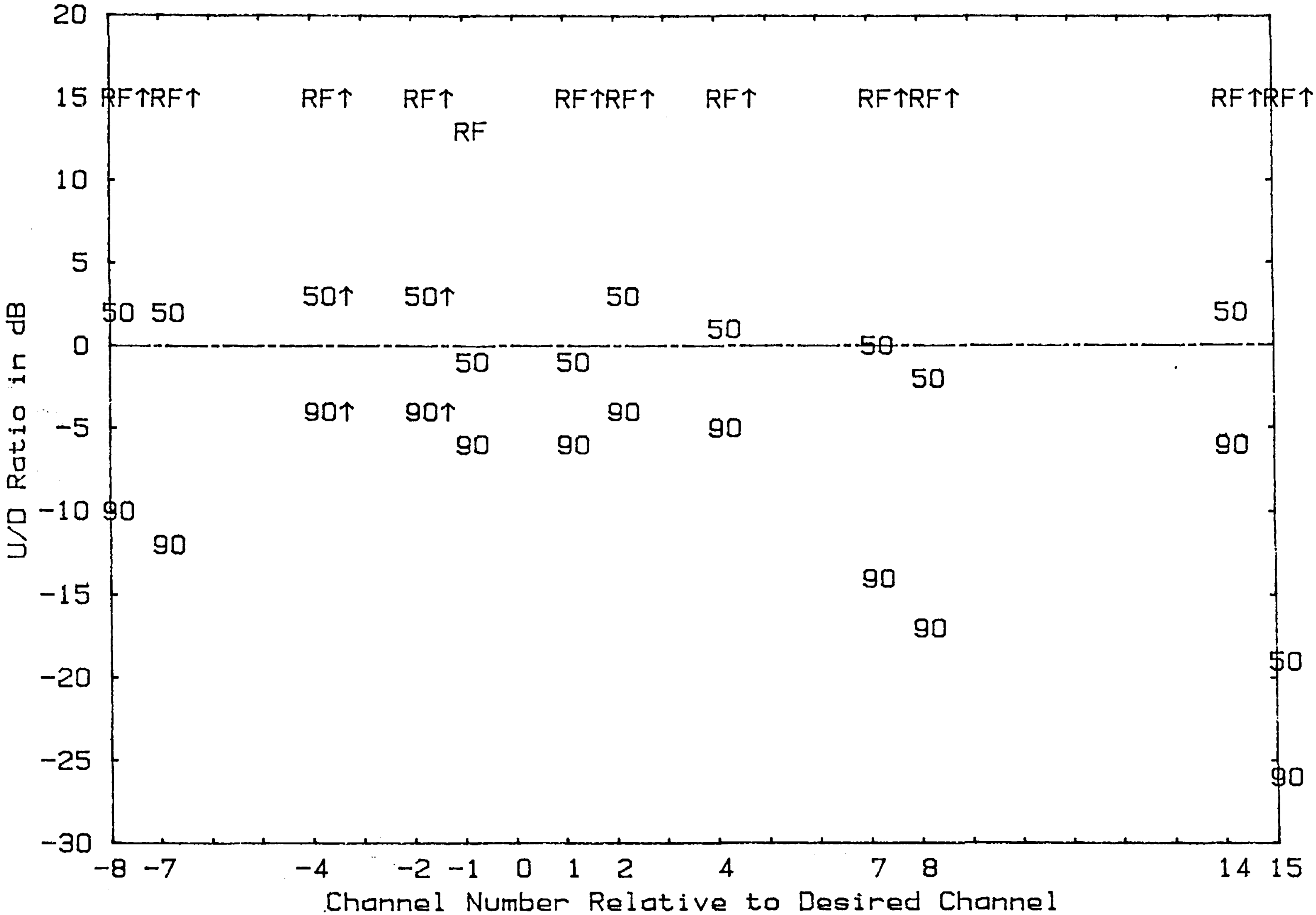
Using the 90 percentile receiver performance protection criterion, we observe from Figure 1 that the taboo channels as viewed in the context of conventional receivers, can generally be grouped into three ranges:

1) -4 to -6 dB

2) -10 to -17 dB (Channels n + or - 7 and + or - 8); and,

3) -26 dB (Channel n + 15).

Fig. 1: Strong Signal Receiver Performance: RF Monolithics, 50%, 90% Protection



Assuming that ATV augmentation signals are transmitted at power levels 4 to 6 dB lower than the primary signal, it appears that channels +1, - 1, +2, -2, +3, -3, +4, -4, +5, -5, +14, and -14 from the tuned channel (those in the first group) are the best candidates for augmentation channels. 10 These channels represent the adjacent channel, intermodulation, and sound image taboos. Channels +7, -7, +8, and -8 from the tuned channel (those in the second group) appear less desirable for use as augmentation channels. These channels represent the oscillator taboo, which is treated in this study as an IF beat phenomenon, and the IF beat taboo. Finally, the channel +15 from the tuned channel (the third group) appears the least likely candidate for augmentation channels. This channel is the picture image taboo.

In summary, the results of the study suggest that the adjacent channels, intermodulation channels, and sound image channels are the best candidates for collocated ATV augmentation signal channels. The IF beat channels are not as good, and the picture image channel is the poorest. We believe these observations are generally conservative, given the design of the analysis on which they are based. In particular, the study used:

1) The "just perceptible" interference criterion (This degree of interference is not expected to be noticeable under ordinary viewing conditions);

2) Protection of the receiver population based on the 90 percentile U/D interference immunity ratios;

3) Adjustments of the sample means so that the estimated population means from the sample data were the lower bound of the 90 percent confidence interval; and,

4) Conventional television signals on the taboo channels. (Carrier-related interference caused by conventional television signals will probably not be characteristic of ATV augmentation signals which are likely to avoid such effects.)

Some cautions in interpreting the results of this study are in order, however. The study results are based on a rather limited sample of receivers. It is possible that the actual population of receivers could tend to be more (or less) subject to taboo channel interference than indicated by this study. Also, the receivers used were models marketed in 1983. While we do not believe that the performance characteristics of electronic tuners have changed significantly since that time, we do not know for certain how these receivers compare to receivers on the market now. Further, although this study recommends the use of receiver interference immunity U/D ratios that would protect an estimated 90 percent of receivers, 10 percent of the receivers in a

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10 Taboo channels 3 and 5 channels removed from the tuned channel can be expected to have better (larger) U/D ratios than taboo channels 2 and 4 channels removed and therefore were not separately examined in this study. See footnote 6 above.

particular area could be affected by taboo interference. This could still result in a reduction of service to a large number of households. Finally, it is possible that on some receivers the effects of some interference phenomena may change precipitously from "just perceptible" to a much worse condition. This study did not investigate the likelihood of such effects occurring.

We also observe that advanced technology exists that would make the restrictions imposed by the present taboos unnecessary. This is apparent from the measured performance of the RF Monolithics receiver as shown on Figure 1. A new generation of television receivers incorporating this technology could be produced that would be relatively immune to interference resulting from UHF taboo combinations. Thus, taboo related interference is expected to be a problem only during a transition period in which improved receivers are introduced, but it appears that even during the transition period there would only be a few taboo channels that could not be used for augmentation signals.

We plan to undertake additional receiver test and analysis programs that will improve our statistical inferences. These may involve larger sample sizes for increased confidence in extensions of the sample to the receiver population. We also plan to improve our sampling techniques and to observe time-dependent trends in the interference immunities of the receiver population.

APPENDIX A

Brief Descriptions of the UHF Taboo Phenomena as Set Forth in the FCC's Rules ("n" is the number of the tuned channel)

<u>Adjacent Channel (n + or - 1 channel)</u>

Adjacent channel minimum mileage separations also apply to VHF television. All receivers are more or less susceptible to signals immediately adjacent to their intended passband.

<u>Intermodulation (n + or - 2, 3, 4, 5 channels)</u>

Intermodulation from a combination of input signals produces a spurious signal or signals within the tuned channel. For example in television, a spurious signal on a desired visual carrier frequency could arise from the combination, 2fa - fb, where fa is the visual carrier frequency of one undesired channel and fb is the visual carrier frequency of another.

Interference which could occur from channel n+4 is included in the channels listed above. This is called half-IF interference and is attributed to a combination of the undesired signal and a receiver's local oscillator.

Cross modulation interference channels are also included above. In television interference the phenomenon typically involves the transfer of the modulation of an undesired visual carrier to the desired visual carrier. Usually, the vertical and horizontal boundaries of the undesired picture are seen first.

<u>Oscillator (n + or - 7 channels)</u>

A UHF television receiver's local oscillator frequency for a tuned channel "n" is located in channel n+7. Therefore, local oscillator radiation from a receiver tuned to channel n could cause cochannel interference to another nearby receiver tuned to channel n+7. The cochannel local oscillator signal is nominally at 3.75 MHz above the lower edge of channel n+7. This is a region of receiver vulnerability to cochannel interference. Protection against such interference is based on the principle of preventing overlapping Grade A service areas of full power UHF stations seven channels apart, so that receivers within the Grade A service area of one such station would not normally be tuned to receive service from the other station which would not be as good in quality.

IF beat interference, described below, could also occur for the above channel separations.

IF Beat (n + or - 8 channels)

When two stations are separated by a receiver's intermediate frequency (IF), it is possible that the two stations' signals will combine to produce a beat signal which will be picked up by a receiver's IF amplifier. Where a 45.75 MHz IF is in use, such signals may exist for channels which are separated by seven or eight channels from the desired station's channel. (The seven channel separation is subsumed by the restriction based on receiver oscillator radiation.)

Sound Image (n + or - 14 channels)
Picture Image (n + or - 15 channels)

Image interference arises from signals in a receiver's image channel band. This band is located as much above a receiver's local oscillator frequency as the desired channel is below it. One frequency in the image channel is the aural carrier frequency of the sound image channel (n+14). Another is the visual carrier frequency of the picture image channel (n+15).

The visual carrier frequency of the picture image channel is in a more vulnerable part of a receiver's image channel than the aural carrier of the sound image channel. The lower amplitude of a television channel's aural carrier compared to its visual carrier also reduces interference effects of the sound image channel compared to the picture image channel.

APPENDIX B
UHF Television Interference Test Procedures

For tests of the 1983 sample, two engineers experienced in picture quality judgements made subjective observations of "just perceptible" interference. Interfering signal levels were read to the nearest decibel in dBm, decibels referred to one milliwatt. If the data from the two observers were within two decibels, the mean was reported; otherwise the appropriate observations would be repeated until the two decibel range was obtained. (This latter procedure was necessary in relatively few cases.)

In making an interference level judgement, an observer was seated at a distance of four to six times the picture height from the face of the television receiver's picture tube. No light source was directed at the screen and specular reflections were avoided on the face of the picture tube. The room was illuminated with somewhat less light than may be typical in ordinary home viewing.

With the television channel combinations established for a particular test, the level of the desired signal was set to the specified value. The levels of the interfering signal(s) were controllable through a single attenuator by the observer. His observations of the interfering signal level for the criterion of "just perceptible" interference was obtained by adjusting the attenuator to the point at which a few dB increase gave an obvious visible interference while an equal decrease caused the visible effect to disappear; i.e., become imperceptible.

In previous tests of this kind, notably for tests reported in 1974, three observers were used, and the desired signal and undesired signal(s) were translated broadcast television signals. With three observers there was always a center value (the median) to allow for a relatively wide range of observations caused by the various video conditions present during programming. (Commercials were not used for observations because of their frequent shifts of scene and eye-catching effects.) Of course the use of program material represented actual viewing conditions of luminance and chrominance.

However, in this study changes were necessary because of constraints of time and available personnel. To reduce observation time, a test pattern was used on the desired channel instead of program material. This eliminated time previously spent waiting for usable video. This decision also eliminated differences in desired video during observations, making the use of only two observers acceptable.

The visual carrier of the desired signal was modulated with a 50% average picture level full-screen pedestal with color burst. Its aural carrier was unmodulated. As in the previous tests, the undesired television signal(s) were translated broadcast television signals. This maintained effects observable because of such characteristics as lack of frame synchronization and saturation changes in the undesired programming. The procedure used for these tests was judged acceptable, based on data which agreed within plus or minus 4 dB, obtained under the previous and present conditions with a control receiver.

APPENDIX C

Supplementary Results of Study

Adjacent Channel

Upper Adjacent Channel (n+1)

Weak Desired Signal (-55 dBm):

The data were not normalizable. The results below for n-1, weak desired signal, may be used for purposes of illustration. The sample statistics indicate somewhat poorer receiver immunities for n-1.

Moderate Desired Signal (-35 dBm): Conditionally normal

U/D = -10 dB (Protects 99% of represented population)
U/D = 0 dB (Protects 90% of represented population)
U/D = 3 dB (Protects 80% of represented population)
U/D = 9 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm): Conditionally normal

U/D = -12 dB (Protects 99% of represented population)
U/D = -6 dB (Protects 90% of represented population)
U/D = -4 dB (Protects 80% of represented population)
U/D = -1 dB (Protects 50% of represented population)

Lower Adjacent Channel (n-1)

Weak Desired Signal (-55 dBm): Conditionally normal

U/D = -16 dB (Protects 99% of represented population)
U/D = -6 dB (Protects 90% of represented population)
U/D = -1 dB (Protects 80% of represented population)
U/D = 8 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm): Conditionally normal

U/D = -16 dB (Protects 99% of represented population)
U/D = -6 dB (Protects 90% of represented population)
U/D = -2 dB (Protects 80% of represented population)
U/D = 5 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm): Conditionally normal, population U/D expected to be better than below since one data point > 15 dB was not used.

U/D = -12 dB (Protects 99% of represented population)
U/D = -6 dB (Protects 90% of represented population)
U/D = -4 dB (Protects 80% of represented population)
U/D = -1 dB (Protects 50% of represented population)

APPENDIX C
(Continued)

Intermodulation

Intermodulation Channels (n-2, n-4)

Weak Desired Signal (-55 dBm): Conditionally normal

U/D = 11 dB (Protects 99% of represented population)
U/D = 16 dB (Protects 90% of represented population)
U/D = 17 dB (Protects 80% of represented population)
U/D = 21 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm):

U/D = 6 dB (Protects 99% of represented population)
U/D = 10 dB (Protects 90% of represented population)
U/D = 11 dB (Protects 80% of represented population)
U/D = 14 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm):

U/D = -9 dB (Protects 99% of represented population)
U/D = -4 dB (Protects 90% of represented population)
U/D = -2 dB (Protects 80% of represented population)
U/D = 1 dB (Protects 50% of represented population)

Intermodulation Channels (n+2, n+4) Dominated by Half-IF Channel (n+4).

Weak Desired Signal (-55 dBm): Conditionally normal

U/D = -8 dB (Protects 99% of represented population)
U/D = 2 dB (Protects 90% of represented population)
U/D = 5 dB (Protects 80% of represented population)
U/D = 12 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm):

U/D = -9 dB (Protects 99% of represented population)
U/D = -2 dB (Protects 90% of represented population)
U/D = 1 dB (Protects 80% of represented population)
U/D = 6 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm):

U/D = -12 dB (Protects 99% of represented population)
U/D = -6 dB (Protects 90% of represented population)
U/D = -4 dB (Protects 80% of represented population)
U/D = 0 dB (Protects 50% of represented population)

APPENDIX C
(Continued)

Cross Modulation

Cross Modulation Channel (n+2)

Weak Desired Signal (-55 dBm):

U/D = 10 dB (Protects 99% of represented population)
U/D = 17 dB (Protects 90% of represented population)
U/D = 20 dB (Protects 80% of represented population)
U/D = 25 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm):

U/D = 0 dB (Protects 99% of represented population)
U/D = 8 dB (Protects 90% of represented population)
U/D = 11 dB (Protects 80% of represented population)
U/D = 17 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm): Conditionally normal, population U/D expected to be better than below since one data point > 15 dB was not used.

U/D = -9 dB (Protects 99% of represented population)
U/D = -4 dB (Protects 90% of represented population)
U/D = -2 dB (Protects 80% of represented population)
U/D = 3 dB (Protects 50% of represented population)

Cross Modulation Channel (n-2)

Weak Desired Signal (-55 dBm):

U/D = 17 dB (Protects 99% of represented population)
U/D = 21 dB (Protects 90% of represented population)
U/D = 23 dB (Protects 80% of represented population)
U/D = 27 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm):

U/D = 7 dB (Protects 99% of represented population)
U/D = 13 dB (Protects 90% of represented population)
U/D = 16 dB (Protects 80% of represented population)
U/D = 20 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm):

The data were not normalizable. The results above for n+2, strong desired signal, will be used for purposes of illustration. The sample statistics indicate somewhat poorer receiver immunities for n+2.

Cross Modulation

Cross Modulation Channel (n-4)

Weak Desired Signal (-55 dBm):

U/D = 22 dB (Protects 99% of represented population)
U/D = 30 dB (Protects 90% of represented population)
U/D = 31 dB (Protects 80% of represented population)
U/D = 36 dB (Protects 50% of represented population)

Moderate and Strong Desired Signals (-35 and -15 dBm):

Neither of these data sets were normalizable. The sample statistics show increased receiver immunities compared to the n+2 and n-2 cross modulation channel separations. Results for n+2 will be used for purposes of illustration.

Half-IF (n+4)

Weak Desired Signal (-55 dBm):

The data were not normalizable. The results above for n+2, n+4, weak desired signal, may be used for purposes of illustration. The sample statistics indicate that the receiver immunities are similar.

Moderate Desired Signal (-35 dBm):

U/D = -7 dB (Protects 99% of represented population)
U/D = -1 dB (Protects 90% of represented population)
U/D = 2 dB (Protects 80% of represented population)
U/D = 7 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm): Conditionally normal, population U/D expected to be better than below since one data point > 15 dB was not used.

U/D = -11 dB (Protects 99% of represented population)
U/D = -5 dB (Protects 90% of represented population)
U/D = -3 dB (Protects 80% of represented population)
U/D = 1 dB (Protects 50% of represented population)

APPENDIX C
(Continued)

IF Beat

IF Beat Channel (n+7)

Weak Desired Signal (-55 dBm):

U/D = -2 dB (Protects 99% of represented population)
U/D = 10 dB (Protects 90% of represented population)
U/D = 14 dB (Protects 80% of represented population)
U/D = 23 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm): Conditionally normal, population U/D expected to be better than below since one data point > 35 dB was not used.

U/D = -24 dB (Protects 99% of represented population)
U/D = -8 dB (Protects 90% of represented population)
U/D = -2 dB (Protects 80% of represented population)
U/D = 10 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm): Conditionally normal, population U/D expected to be better than below since two data points > 15 dB were not used.

U/D = -26 dB (Protects 99% of represented population)
U/D = -14 dB (Protects 90% of represented population)
U/D = -11 dB (Protects 80% of represented population)
U/D = 0 dB (Protects 50% of represented population)

IF Beat Channel (n-7)

Weak Desired Signal (-55 dBm):

U/D = -6 dB (Protects 99% of represented population)
U/D = 6 dB (Protects 90% of represented population)
U/D = 12 dB (Protects 80% of represented population)
U/D = 22 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm): Conditionally normal, population U/D expected to be better than below since one data point > 35 dB was not used.

U/D = -15 dB (Protects 99% of represented population)
U/D = -2 dB (Protects 90% of represented population)
U/D = 3 dB (Protects 80% of represented population)
U/D = 13 dB (Protects 50% of represented population)

IF Beat Channel (n-7) (continued)

Strong Desired Signal (-15 dBm): Conditionally normal, population U/D expected to be better than below since two data points > 15 dB were not used.

U/D = -24 dB (Protects 99% of represented population)
U/D = -12 dB (Protects 90% of represented population)
U/D = -8 dB (Protects 80% of represented population)
U/D = 2 dB (Protects 50% of represented population)

IF Beat Channel (n+8)

Weak Desired Signal (-55 dBm): Conditionally normal

U/D = -29 dB (Protects 99% of represented population)
U/D = -5 dB (Protects 90% of represented population)
U/D = 4 dB (Protects 80% of represented population)
U/D = 21 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm): Conditionally normal

U/D = -38 dB (Protects 99% of represented population)
U/D = -17 dB (Protects 90% of represented population)
U/D = -8 dB (Protects 80% of represented population)
U/D = 9 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm): Conditionally normal, population U/D expected to be better than below since two data points > 15 dB were not used.

U/D = -30 dB (Protects 99% of represented population)
U/D = -17 dB (Protects 90% of represented population)
U/D = -12 dB (Protects 80% of represented population)
U/D = -2 dB (Protects 50% of represented population)

APPENDIX C
(continued)

<u>IF Beat Channel (n-8)</u>

Weak Desired Signal (-55 dBm):

U/D = -3 dB (Protects 99% of represented population)
U/D = 10 dB (Protects 90% of represented population)
U/D = 15 dB (Protects 80% of represented population)
U/D = 26 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm): Conditionally normal, population U/D expected to be better than below since one data point > 35 dB was not used.

U/D = -20 dB (Protects 99% of represented population)
U/D = -5 dB (Protects 90% of represented population)
U/D = 1 dB (Protects 80% of represented population)
U/D = 13 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm): Conditionally normal, population U/D expected to be better than below since three data points > 15 dB were not used.

U/D = -19 dB (Protects 99% of represented population)
U/D = -10 dB (Protects 90% of represented population)
U/D = -6 dB (Protects 80% of represented population)
U/D = 2 dB (Protects 50% of represented population)

APPENDIX C
(Continued)

Image Channels

Sound Image Channel (n+14)

Weak Desired Signal (-55 dBm):

U/D = -12 dB (Protects 99% of represented population)
U/D = -1 dB (Protects 90% of represented population)
U/D = 4 dB (Protects 80% of represented population)
U/D = 13 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm):

U/D = -11 dB (Protects 99% of represented population)
U/D = -2 dB (Protects 90% of represented population)
U/D = 1 dB (Protects 80% of represented population)
U/D = 8 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm):

U/D = -12 dB (Protects 99% of represented population)
U/D = -6 dB (Protects 90% of represented population)
U/D = -3 dB (Protects 80% of represented population)
U/D = 2 dB (Protects 50% of represented population)

Picture Image Channel (n+15)

Weak Desired Signal (-55 dBm):

U/D = -31 dB (Protects 99% of represented population)
U/D = -20 dB (Protects 90% of represented population)
U/D = -15 dB (Protects 80% of represented population)
U/D = -7 dB (Protects 50% of represented population)

Moderate Desired Signal (-35 dBm):

U/D = -22 dB (Protects 99% of represented population)
U/D = -17 dB (Protects 90% of represented population)
U/D = -14 dB (Protects 80% of represented population)
U/D = -10 dB (Protects 50% of represented population)

Strong Desired Signal (-15 dBm):

U/D = -31 dB (Protects 99% of represented population)
U/D = -26 dB (Protects 90% of represented population)
U/D = -24 dB (Protects 80% of represented population)
U/D = -19 dB (Protects 50% of represented population)